AN INTRODUCTION TO HYDROGEOMORPHIC (HGM) FUNCTIONAL STREAM ASSESSMENT

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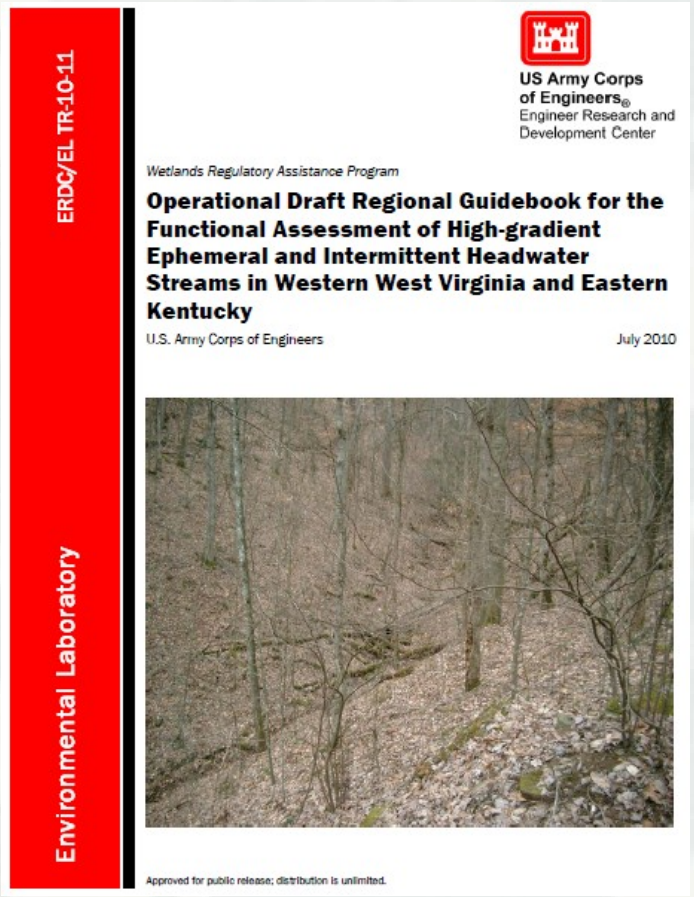
Purpose of HGM Approach

- To assess the capacity of a stream reach to perform functions relative to similar streams in a region
- Ecosystem functions assessed through measures of commonly identified structural components important to stream function and simple logic models

Purpose of Workshop

- Provide an overview of the Draft Guidebook
- Introduce basic concepts and terms
- How to conduct the HGM assessment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Wetlands Regulatory Assistance Program
Operational Draft Regional Guidebook for the Functional Assessment of High-gradient Ephemeral and Intermittent Headwater Streams in Western West Virginia and Eastern Kentucky
U.S. Army Corps of Engineers
July 2010
Approved for public release; distribution is unlimited.

What Are Functions?

- Processes or activities that take place in ecosystems
- “Things that ecosystems do”

Examples of Stream Functions

- Hydrology
  - Transport water downstream
  - Dissipate energy of currents
- Biogeochemical Cycling
  - Retain and transform inorganic materials needed for biological processes into organic forms
  - Oxidize those organic molecules back into elemental forms through respiration
- Habitat
  - Support for plant and animal communities

Functions versus Values

- Values are beneficial goods and services resulting from functions
- “Value” is the relative importance of something to an individual or group (e.g., to society)
- The HGM Approach assesses functions, but does not determine values

What is Functional Capacity?

- The degree or magnitude to which a ecosystem performs a function
- Depends on characteristics of the ecosystem and the surrounding landscape
- Similar ecosystems exhibit a range of functional capacities due to inherent characteristics, natural disturbance, and anthropogenic alteration

What is the HGM Approach?

- A method for assessing the functional capacity of an ecosystem
- Three pillars of the HGM Approach:
  - ► Hydrogeomorphic classification
  - ► Reference sites
  - ► Assessment models
- End result is a rapid assessment technique for the user

Regional Subclasses

- Applying classification to a specific geographic area leads to regional subclasses
  - ► High-gradient ephemeral and intermittent headwater streams in western WV and eastern KY

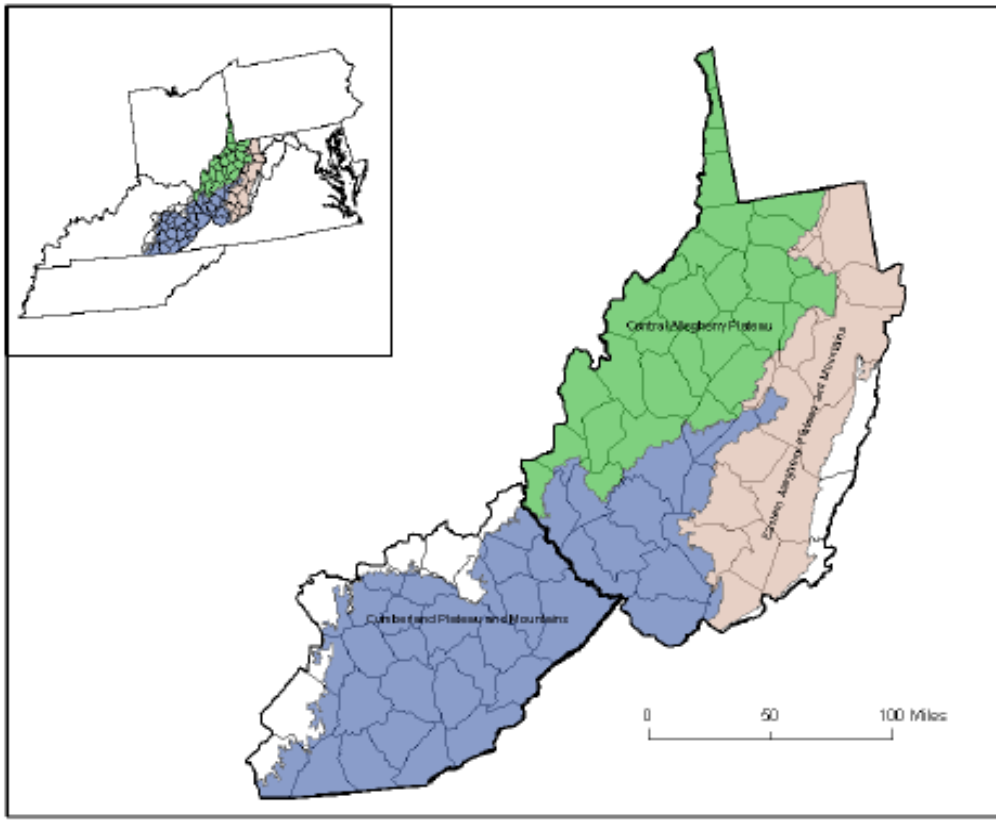

Figure 3. Map of the reference domain for high-gradient headwater streams in western West Virginia and eastern Kentucky.

Regional Subclasses (continued)

- Regional subclasses are the target for development of HGM assessment models

What are Reference Sites?

- A group of sites that encompasses the range of variability exhibited by a regional subclass
- Variability results from:
  - Natural processes and disturbance
  - Anthropogenic alteration

What is “Reference Standard” ?

- Streams performing a suite of functions for the regional subclass at a level that is characteristic of the least altered sites in the least altered landscapes
- Of over 90 sites sampled, only 10 sites identified by the A-Team as Reference Standard

Developing Assessment Models

HGM models are designed to estimate functional capacity of a site relative to reference standard sites

$$FCI = \frac{\text{Functional Capacity of the Target Ecosystem (SAR)}}{\text{Functional Capacity of Reference Standard Ecosystem}}$$

Developing Assessment Models

- Functional Capacity depends on characteristics of the ecosystem and the surrounding landscape
- Therefore, HGM models use variables that are measures of site and landscape characteristics:
  - ► Substrate size
  - ► Sediment embeddedness
  - ► Amount of large woody debris

Assessment Models

- Consist of model variables aggregated in an equation to produce a Functional Capacity Index (FCI)

Applications of HGM Models

- Estimate baseline functional capacity
- Estimate impacts of a proposed project
- Evaluate project alternatives
- Determine baseline mitigation requirements
- Estimate the effects of resource management
- Monitor the performance of restored ecosystems

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Information Sources on the Web

- HGM guidebooks and other resources:
  - http://el.erdc.usace.army.mil/wetlands/hgmhp.html
  - http://el.erdc.usace.army.mil/wetlands/datanal.html

QUESTIONS?

HGM VARIABLES

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Site Selection and Stream Assessment Reach (SAR) Determination Scenarios

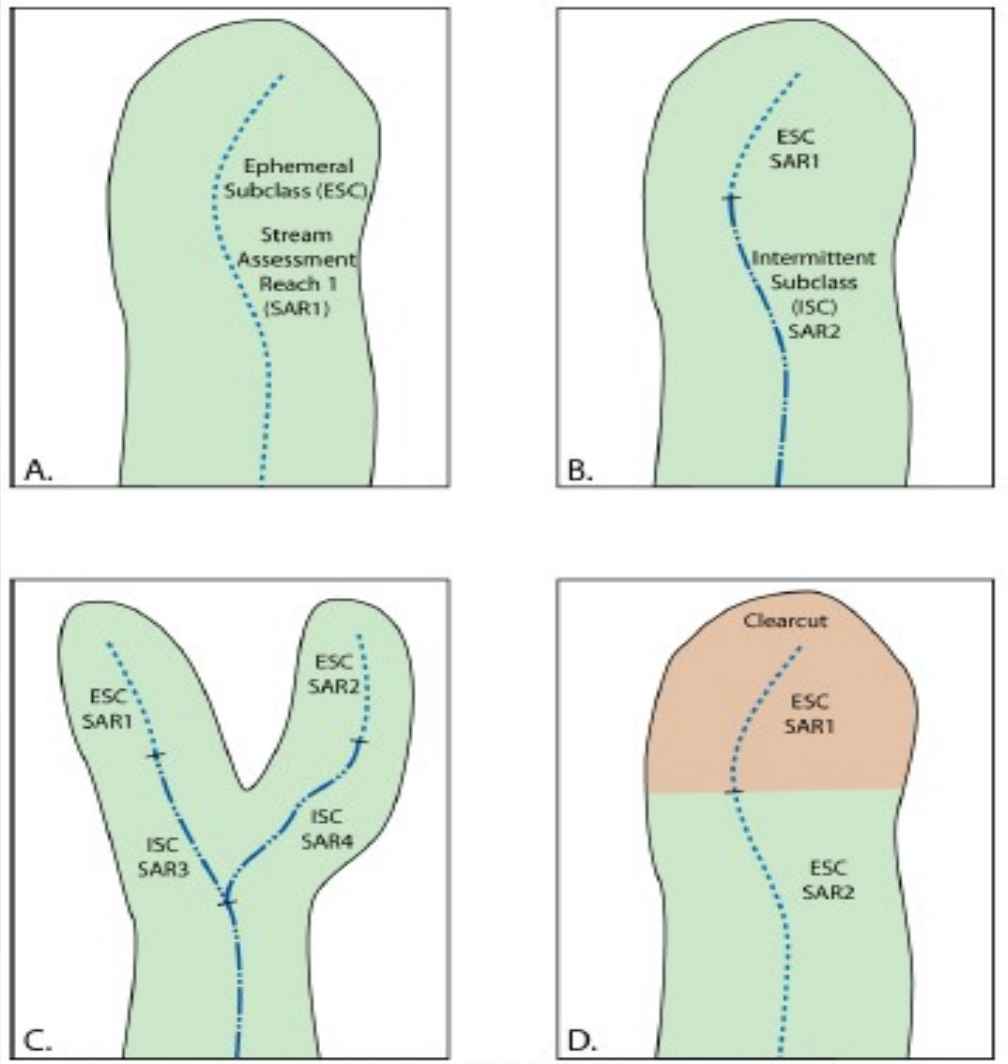
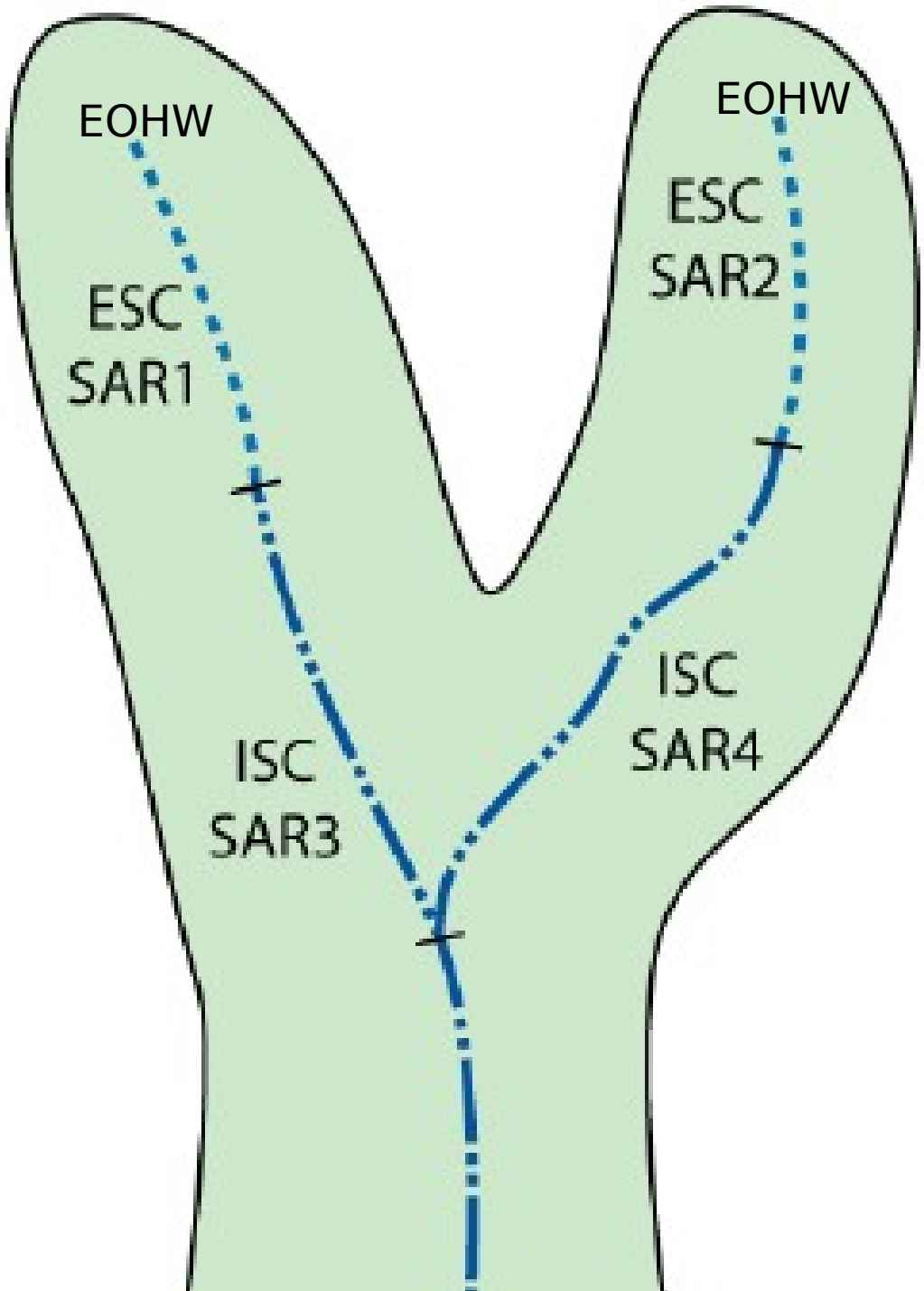


Figure 29. Example of possible SARs and PSARs for high-gradient stream assessments.

- SAR ?’s
  - How Many SARs
  - What’s the Minimum Recommended Reach Length



Variables are

- The things we measure or estimate in the field
  - Used to determine the indices that go into the models to determine functional capacity index (FCI)
- 12 variables have been selected for the High-gradient Headwater guidebook

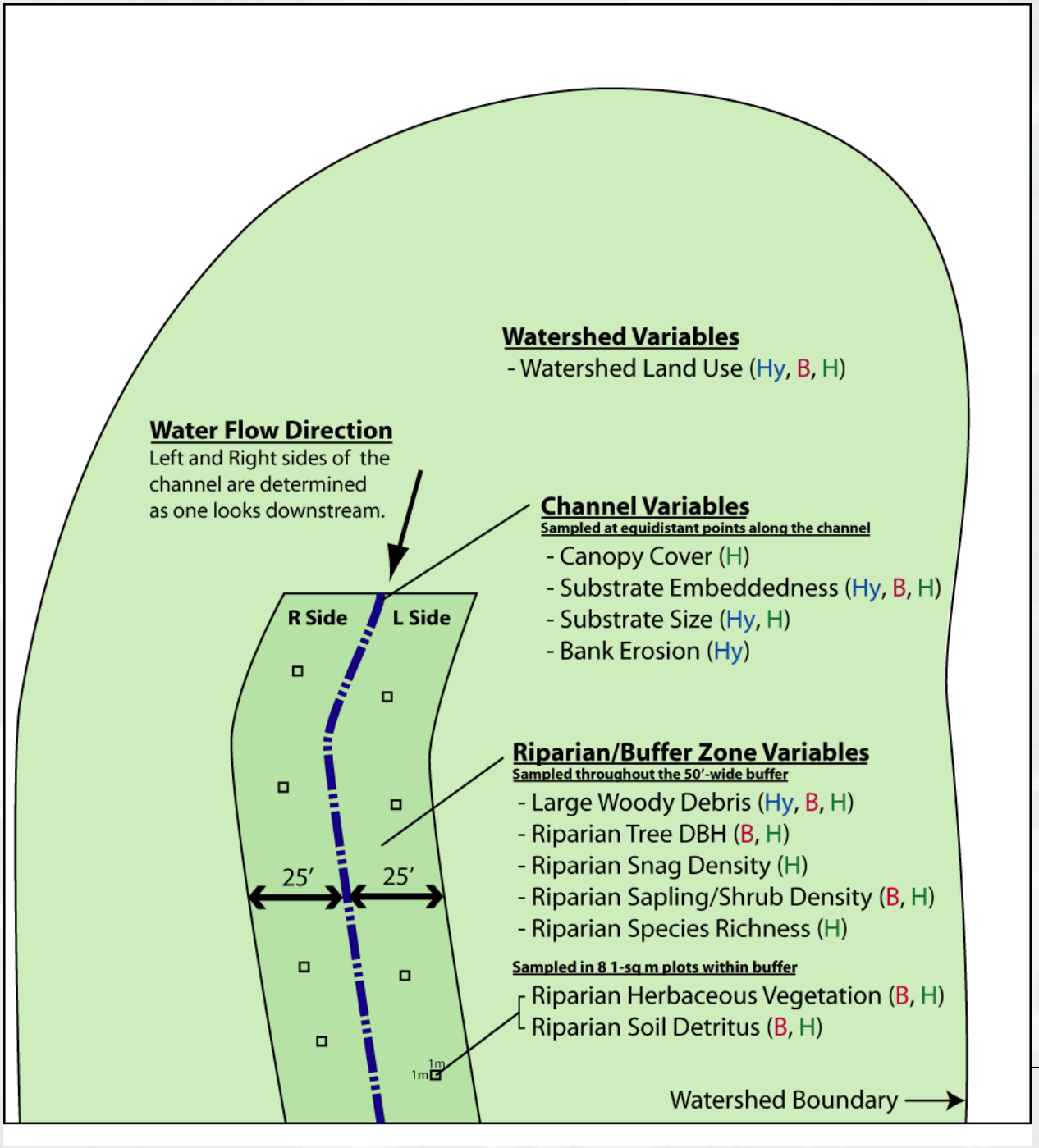
List of the 12 Variables (1-6)

- Channel canopy cover (VCCANOPY)
- Channel substrate embeddedness (VEMBED)
- Channel substrate size (VSUBSTRATE)
- Potential channel bank erosion (VBERO)
- Large Woody Debris (VLWD)
- Riparian/buffer zone tree diameter (VTDBH)

List of the 12 Variables (7-12)

- Riparian/buffer zone snag density (VSNAG)
- Riparian/buffer zone sapling/shrub density (VSSD)
- Riparian/buffer zone species richness (VSRICH)
- Riparian/buffer zone soil detritus (VDETRITUS)
- Herbaceous cover (VHERB)
- Watershed land use (VWLUSE)

Variables Collected for the High-Gradient Ephemeral and Intermittent Headwater Streams in Western West Virginia and Eastern Kentucky HGM Assessment Models


Watershed Variables
- Watershed Land Use (Hy, B, H)
Water Flow Direction
Left and Right sides of the channel are determined as one looks downstream.
Channel Variables
Sampled at equidistant points along the channel
- Canopy Cover (H)
- Substrate Embeddedness (Hy, B, H)
- Substrate Size (Hy, H)
- Bank Erosion (Hy)
R Side
L Side
Riparian/Buffer Zone Variables
Sampled throughout the 50'-wide buffer
- Large Woody Debris (Hy, B, H)
- Riparian Tree DBH (B, H)
- Riparian Snag Density (H)
- Riparian Sapling/Shrub Density (B, H)
- Riparian Species Richness (H)
25'
25'
Sampled in 8 1-sq m plots within buffer
Riparian Herbaceous Vegetation (B, H)
Riparian Soil Detritus (B, H)
1m
1m
Watershed Boundary

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Channel canopy cover ($V_{CCANOPY}$)

- Average % cover of the canopy over the stream channel
- $V_{CCANOPY}$ applies indirectly to all functions and directly to the habitat function

How to measure $V_{CCANOPY}$

1) Tree: all living woody plants >4 in. in diameter at breast height (55 in.) within the stream channel and riparian/buffer zones
2) If no trees (or <20 percent canopy cover) or saplings are present within the riparian/buffer zone or stream channel, then the variable would not be used, and the following steps can be skipped

How to measure $V_{CCANOPY}$ continued

3) Using a densitometer, spherical crown densiometer, or equivalent device designed for estimating percent channel canopy cover, estimate the amount of light obscured by tree branches and leaves
   - This is done while standing in the stream channel within the SAR or PSAR.
4) Minimum of 10 points - approximately evenly spaced along the SAR
   - Longer SARs or those with a diverse canopy may require additional data points

How to measure $V_{CCANOPY}$ continued

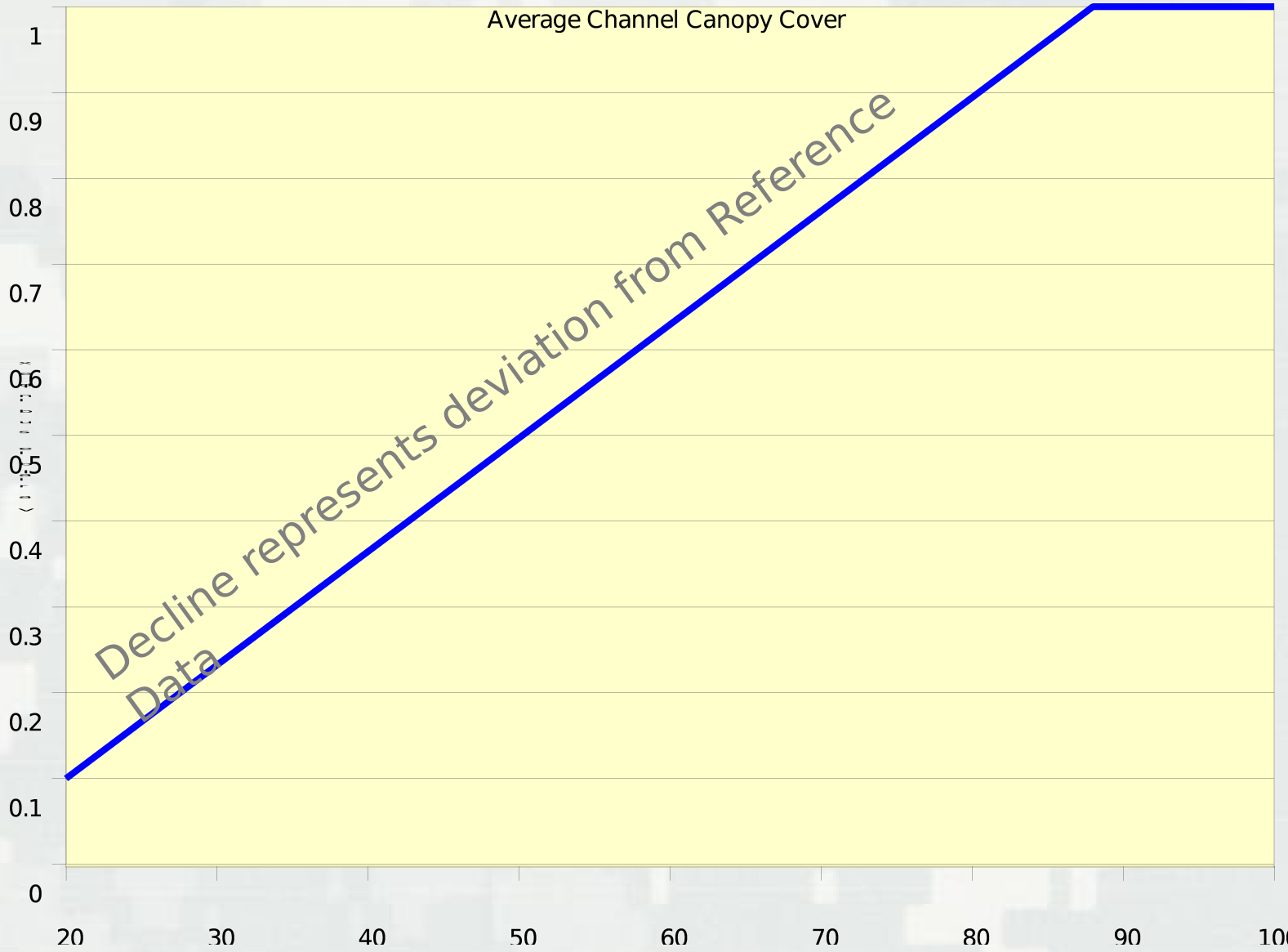
5) Average all of the estimates of percent channel canopy cover
6) Using Figure 9, determine the subindex score for $V_{CCANOPY}$

Examples of Channel canopy cover $V_{CCANOPY}$

Channel with over 90 percent cover

Channel with zero percent cover

≥88%


Average Channel Canopy Cover
Decline represents deviation from Reference
Data
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
30
40
50
60
70
80
90
100

Substrate embeddedness (V_{EMBED})

- This variable is the average embeddedness value of the stream substrate
  - Embeddedness is a measure of the degree to which coarse substrates (gravel, cobble, and boulders) are covered, surrounded, or buried by fine sediments
  - Fine sediments include sand, silt, and clay size (≤0.08 in. (0.2 cm)) particles
  - V_{EMBED} applies to all functions

How to measure V_{EMBED}

1) Emdeddedness is measured concurrently with $V_{SUBSTRATE}$ using the same substrate particle
2) At 30 or more evenly spaced points along the length of the SAR or PSAR select at random substrate particle
   - ► Substrate particles consisting of sand, silt, and clay receive an embeddedness score of 1
   - ► Concrete or other artificial substrate would also receive an embeddedness score of 1
   - ► Areas of bedrock receive an embeddedness score of 5 (Table 4 – pg 23)

How to measure V_{EMBED}
continued

3) Average the embeddedness rating score for all substrate particles measured
4) Using Figure 11, determine the subindex score for V_{EMBED} (pg 25)

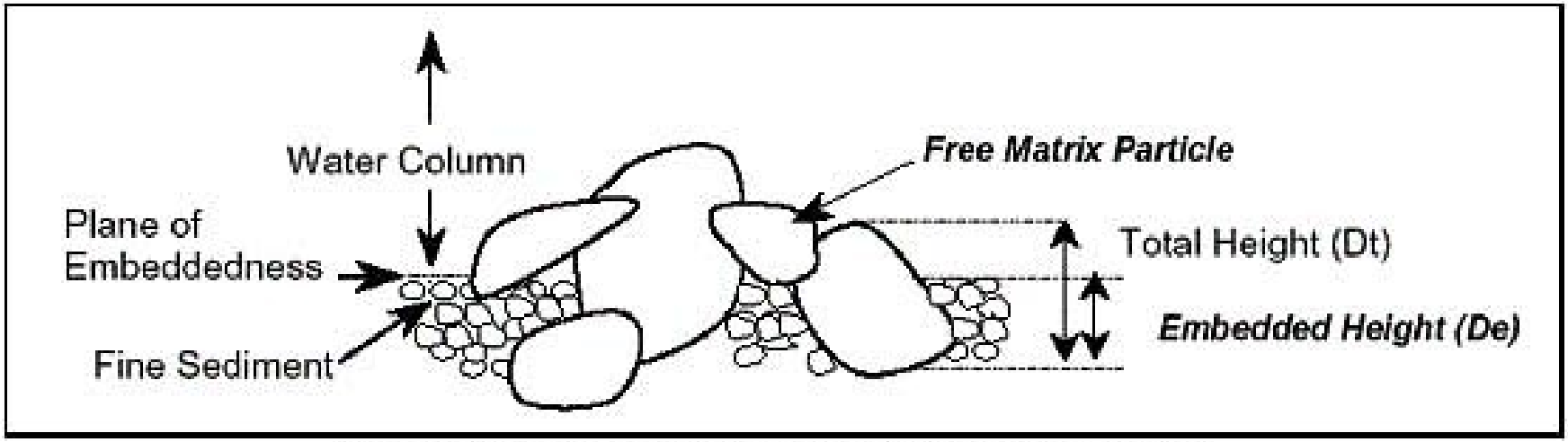
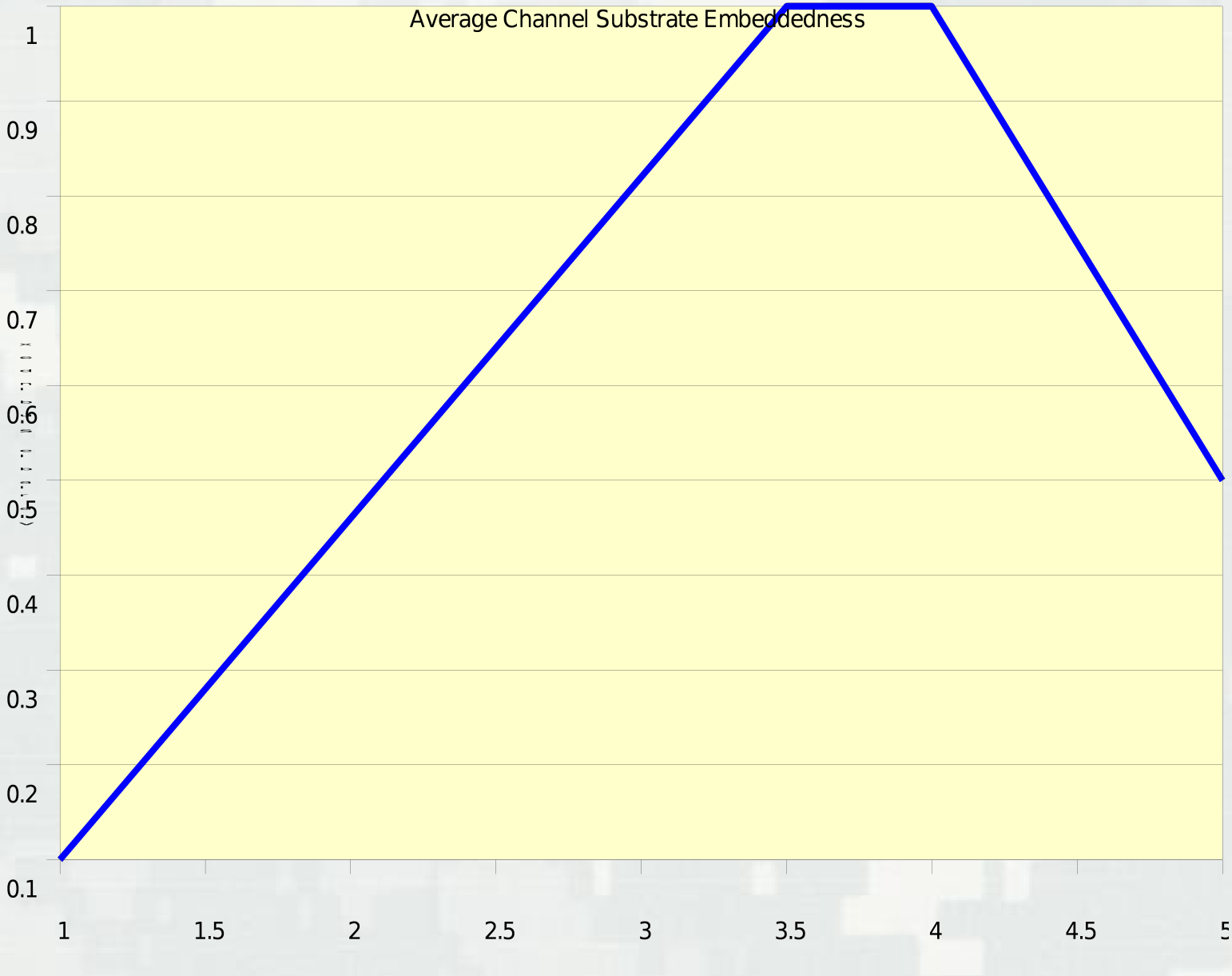


Figure B3. Schematic representation of embeddedness.

Substrate embeddedness V_{EMBED} Table 4

Rating	Rating Description
5	<5 percent of surface covered, surrounded, or buried by fine sediment
4	5 to 25 percent of surface covered, surrounded, or buried by fine sediment
3	26 to 50 percent of surface covered, surrounded, or buried by fine sediment
2	51 to 75 percent of surface covered, surrounded, or buried by fine sediment
1	>75 percent of surface covered, surrounded, or buried by fine sediment

3.5-4 Rating


Average Channel Substrate Embeddedness
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
1.5
2
2.5
3
3.5
4
4.5
5

Substrate embeddedness

V_{EMBED}

embeddedness rating of 5 (<5 % the surface covered by fine sediments

embeddedness rating of 1 (>75 % of the surface covered by fine sediments)

Channel substrate size ($V_{SUBSTRATE}$)

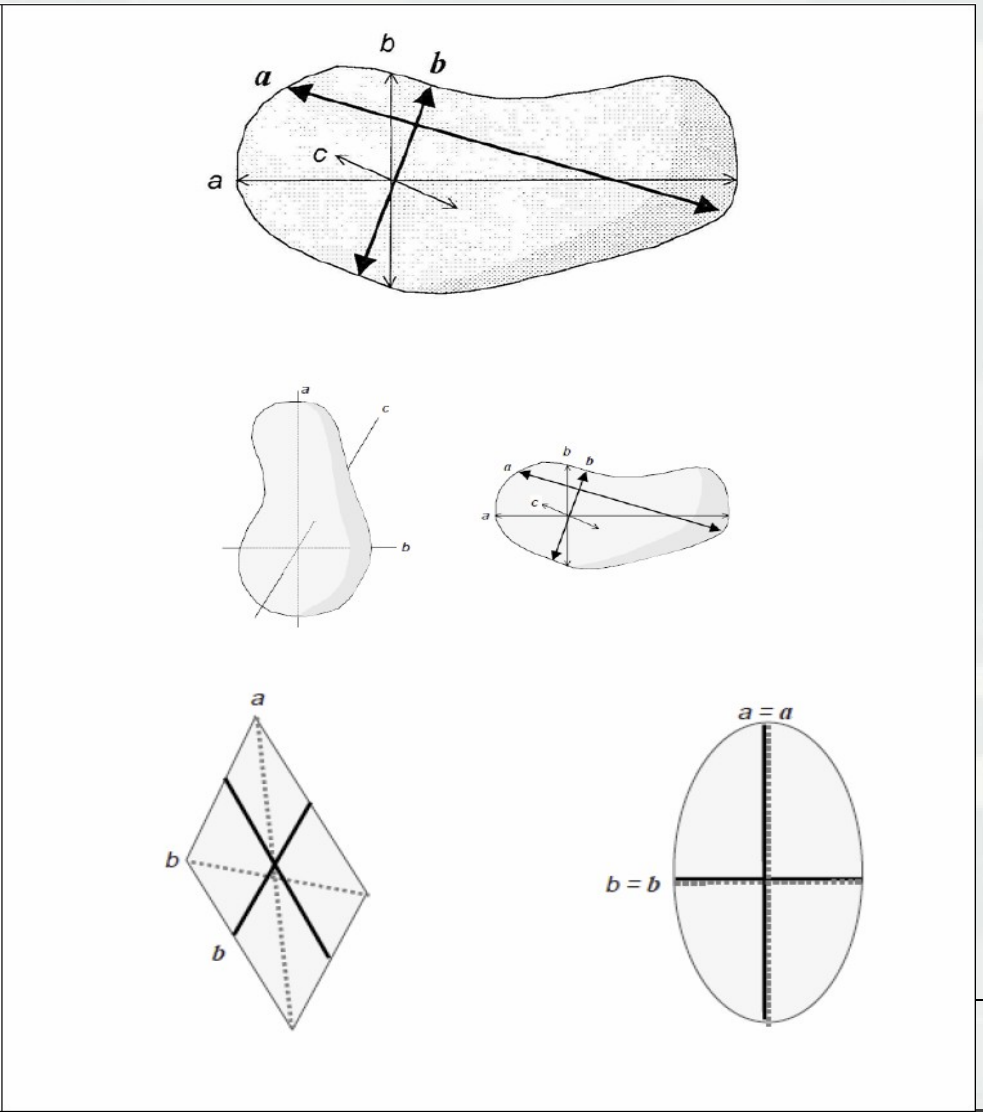
- This variable is the median size of the stream substrate
- $V_{SUBSTRATE}$ only applies to hydrology and habitat functions

How to measure $V_{SUBSTRATE}$

1) Using the same particles selected for V_{EMBED}, measure to the nearest 0.1 in. (3 mm) the size of the particle along the longitudinal (intermediate) axis
2) Bedrock should be counted as 99 in. (251 cm)
3) Concrete or asphalt should be counted as zero
4) Sand or finer size particles can be recorded as 0.08 in. (0.2 cm)
5) Calculate the median value for all particles measured
6) Use Figure 13 to determine the subindex score

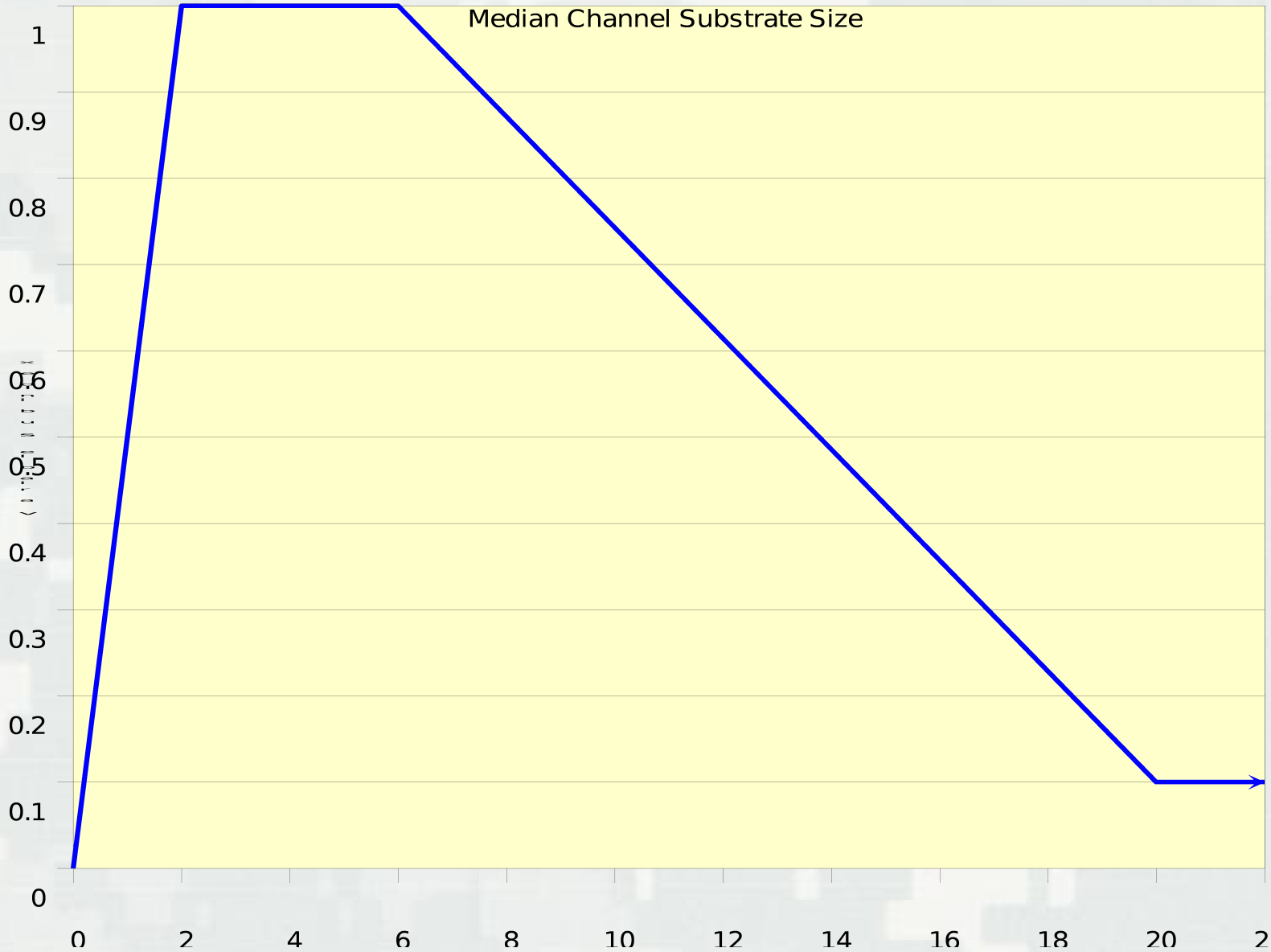
Channel substrate size

$V_{SUBSTRATE}$



Illustrations of the B-axis used for substrate size

2-6 in.


Median Channel Substrate Size
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
18
20
22

Channel substrate size

$V_{SUBSTRATE}$

Median substrate size of 3.7 inches

Median substrate size of 0.08 inches

Potential Channel Bank Erosion (V_{BERO})

- Disturbed, scoured sections of the stream channel bank
- V_{BERO} only applies to the hydrology function

How to measure V_{BERO}

1) While standing in the channel of the SAR or PSAR, measure the length of both the left and right streambanks that display signs of erosion.
2) Record separately the number of feet of left channel bank erosion and right channel bank erosion on the data sheet
3) Total the number of feet of **left descending** and **right descending** channel bank erosion and divide by the length of the stream channel; then multiply by 100 (Equation 7)

$$\left(\frac{\text{ft. left bank erosion} + \text{ft. right bank erosion}}{\text{stream reach length}}\right) \times 100 = \%\ \text{stream channel erosion}$$

4) Use Figure 15 to determine the subindex score for V_{BERO}.

0-14%

Percent Channel Bank Erosion
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
180
200
percent

Potential Channel Bank Erosion (V_{BERO}) *(continued)*

Large Woody Debris (V_{LWD})

- LWD: downed woody stems $\geq$ 4in. in diameter and $\geq$ 36 in. long
- Number of individual pieces of down woody stems per 100 ft (30.5 m) of stream reach within the channel and the riparian/buffer zone
- V_{LWD} applies to all functions

How to measure V_{LWD}

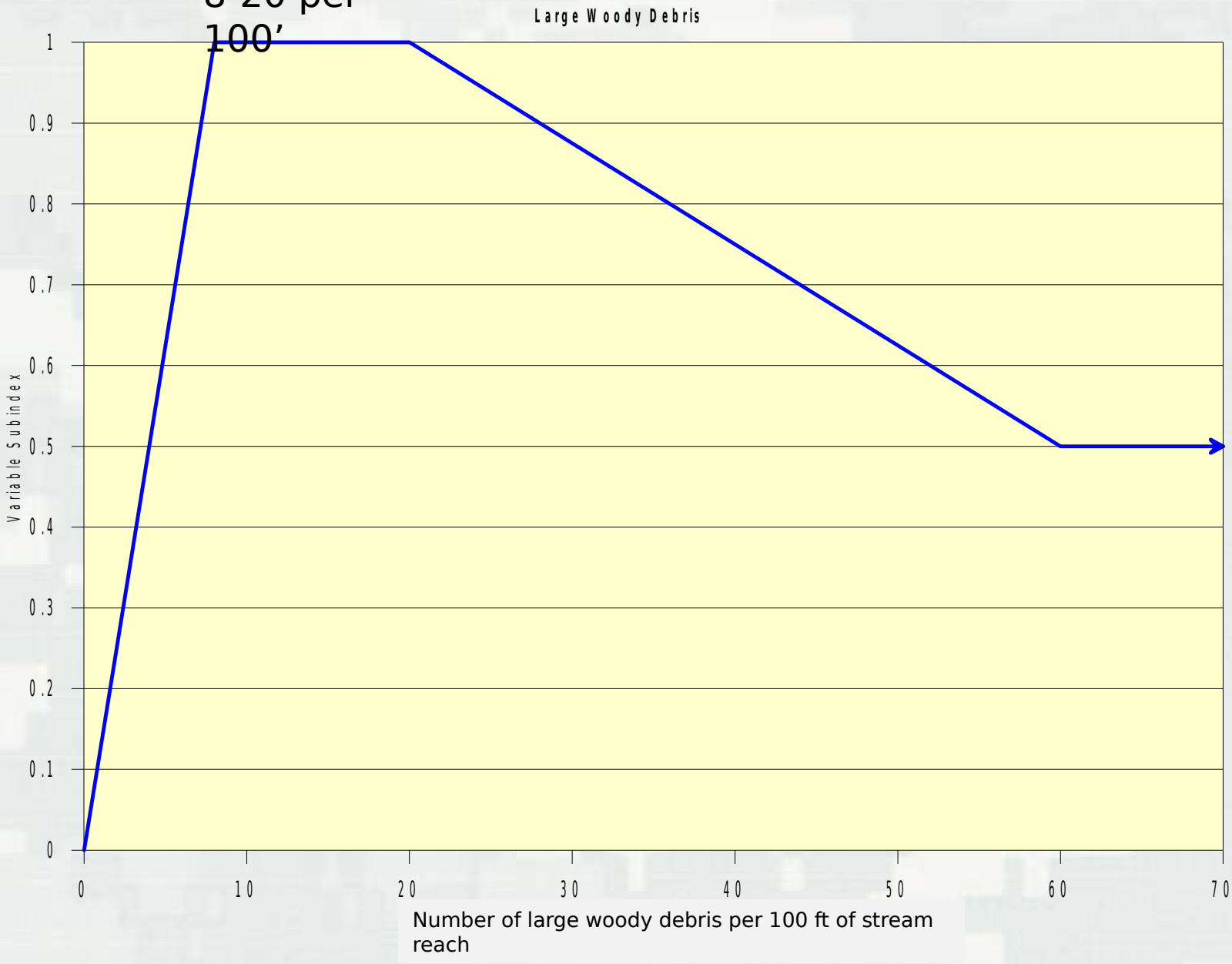
1) Count each individual piece of LWD along the entire SAR or PSAR. Include all LWD located in the riparian/buffer zone and within the stream channel.

2) Record the total number of LWD on the data sheet.

3) Divide the total number of LWD by the length of the SAR or PSAR, then multiply by 100 to determine the number of LWD per 100 ft of stream reach.

4) Use Figure 17 to determine the subindex score for V_{LWD}

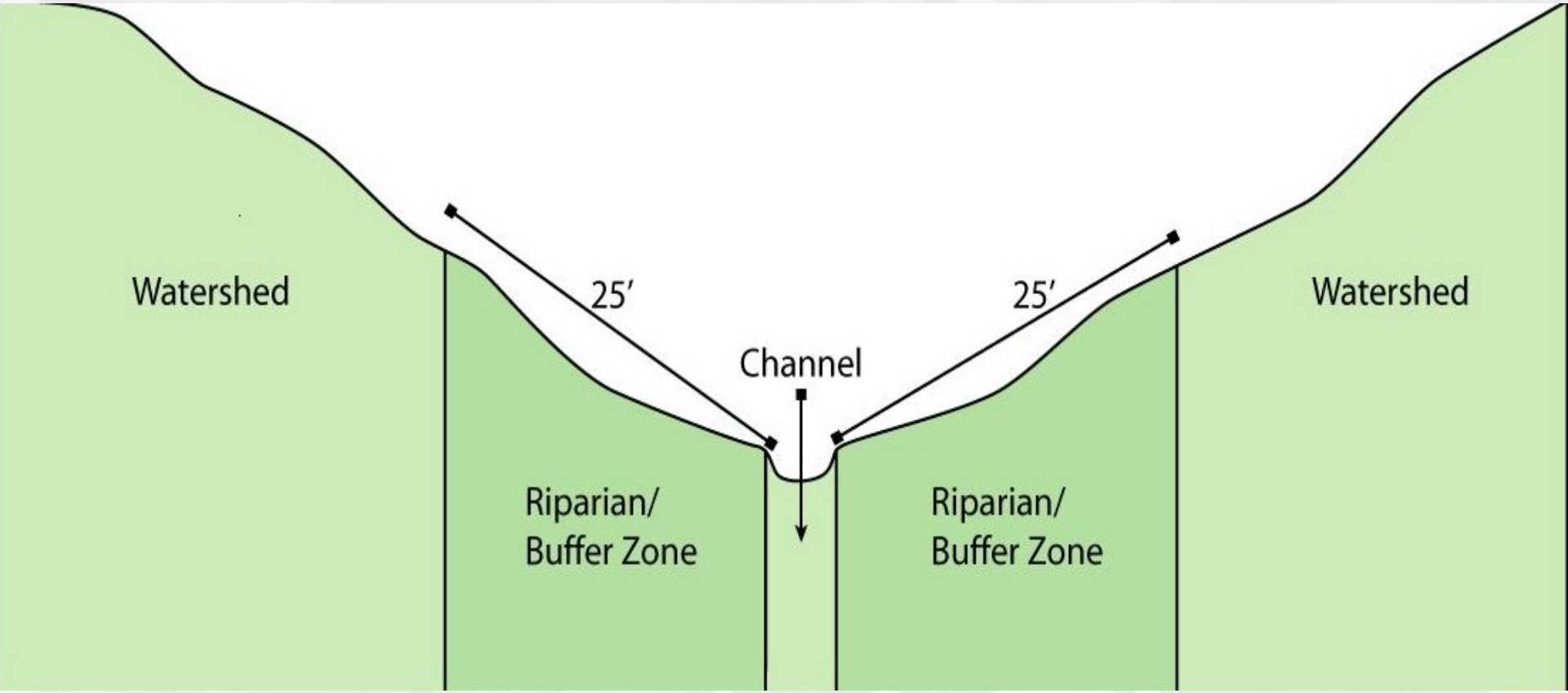
8-20 per 100’


Large Woody Debris
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
Number of large woody debris per 100 ft of stream reach

Riparian/Buffer Zone Tree Diameter (V_{TDBH})

- Trees are defined as woody species ≥4 in. (10 cm) in diameter
- Measurement of average diameter at breast height (dbh) of living woody plants within the channel and riparian/buffer zone
- This variable is collected at stream reaches that contain ≥20 % channel canopy cover ($V_{CCANOPY}$)
- If the channel canopy cover <20%, this variable is not used
- V_{TDBH} applies to the biogeochemistry and habitat functions

Riparian/Buffer Zone



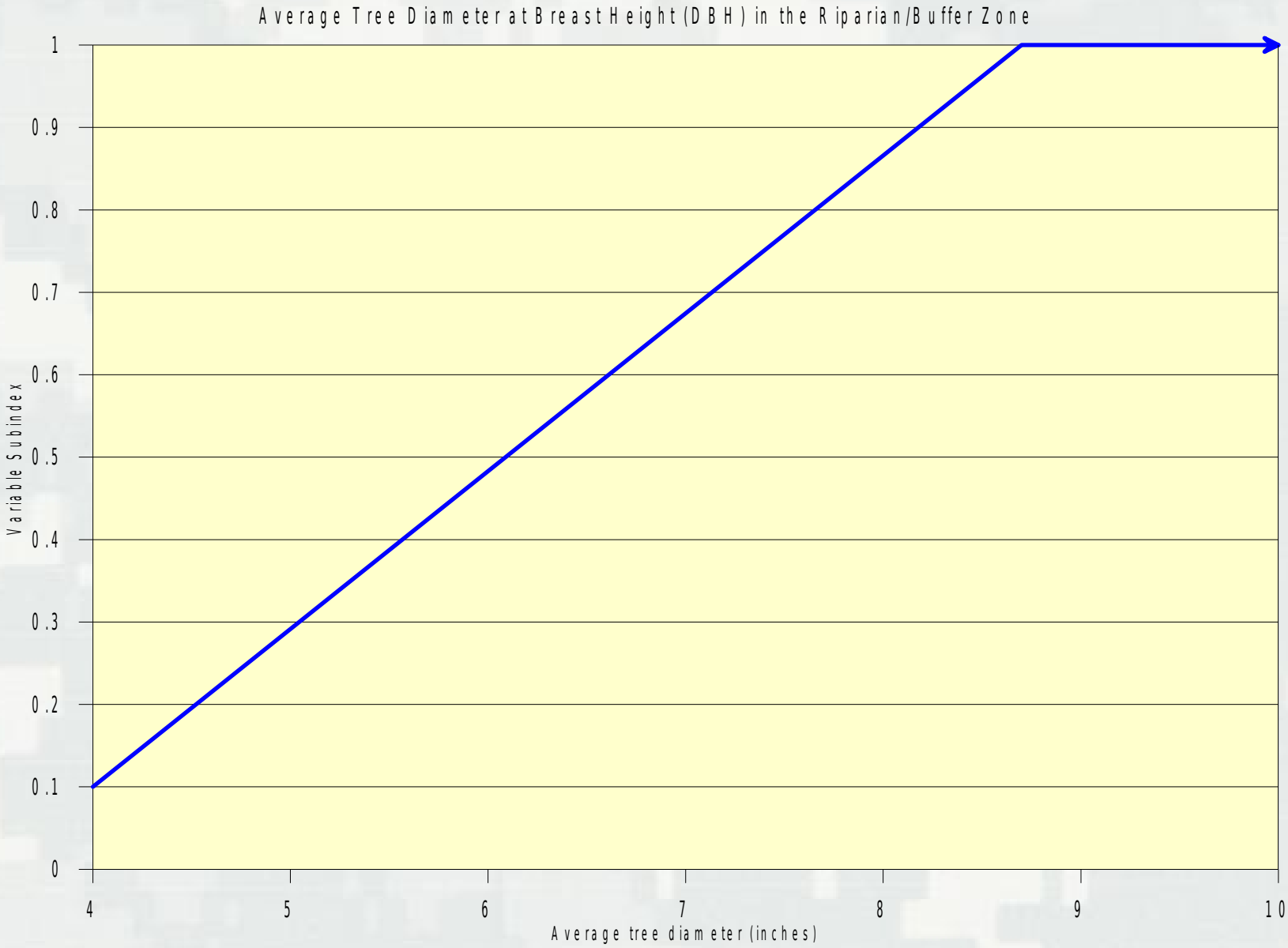
How to measure V_{TDBH}

1) Measure the dbh of all trees within the channel and riparian/buffer zone of the SAR or PSAR
   - ► Measurements should be made using tree calipers, dbh tape, or equivalent device.
   - ► The tree should be measured if any part of the stem is within the riparian/buffer zone.

How to measure V_{TDBH} (continued)

2) Calculate the average tree diameter by summing dbh measurements and dividing by the total number of trees measured.
3) Use Figure 19 to determine the subindex score for V_{TDBH}

≥8.7 in.


Average Tree Diameter at Breast Height (DBH) in the Riparian/Buffer Zone
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4
5
6
7
8
9
10
Average tree diameter (inches)

Riparian/Buffer Zone Tree Diameter (continued)

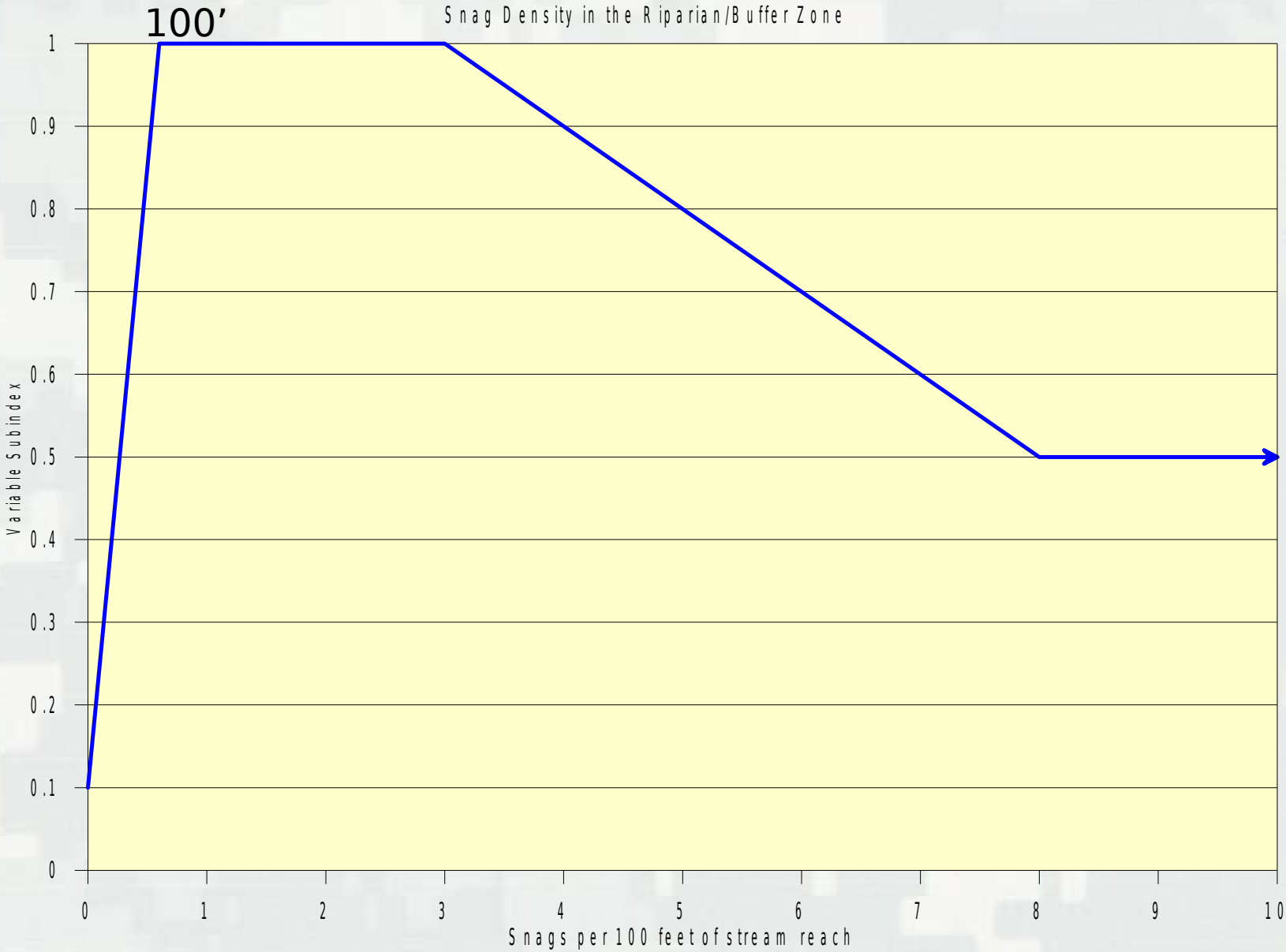
Riparian/buffer zone snag density (V_{SNAG})

- Number of individual snags per 100 ft of the SAR or PSAR within the entire stream channel and riparian/buffer zone.
  - Snags are defined as standing dead trees ≥4 in. (10 cm) in diameter and ≥36 in. (90 cm) in height
  - V_{SNAG} only applies to the habitat function.

How to measure V_{SNAG}

1) Count all snags within the entire riparian/buffer zone, including any snags that occur in the stream channel of the SAR or PSAR
   - Snags should be counted if any part of the stem is within the sample area.
2) Divide the total number of snags by the length of the SAR or PSAR; then multiply by 100 to determine the number of snags per 100 ft of stream reach
3) Use Figure 21 to determine the subindex score for V_{SNAG}

0.6-3.0 per 100’


Snag Density in the Riparian/Buffer Zone
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
Snags per 100 feet of stream reach

Riparian/buffer zone snag density (V_{SNAG})

Riparian/buffer zone sapling/shrub density (V_{SSD})

- Number of woody stems >36 in. (90 cm) in height and <4 in. (10 cm) dbh (e.g., shrubs, saplings, and understory trees) per 100 ft (30.5 m) of stream reach.
- Only measured if channel canopy cover is <20%
- V_{SSD} applies only to the biogeochemistry and habitat functions

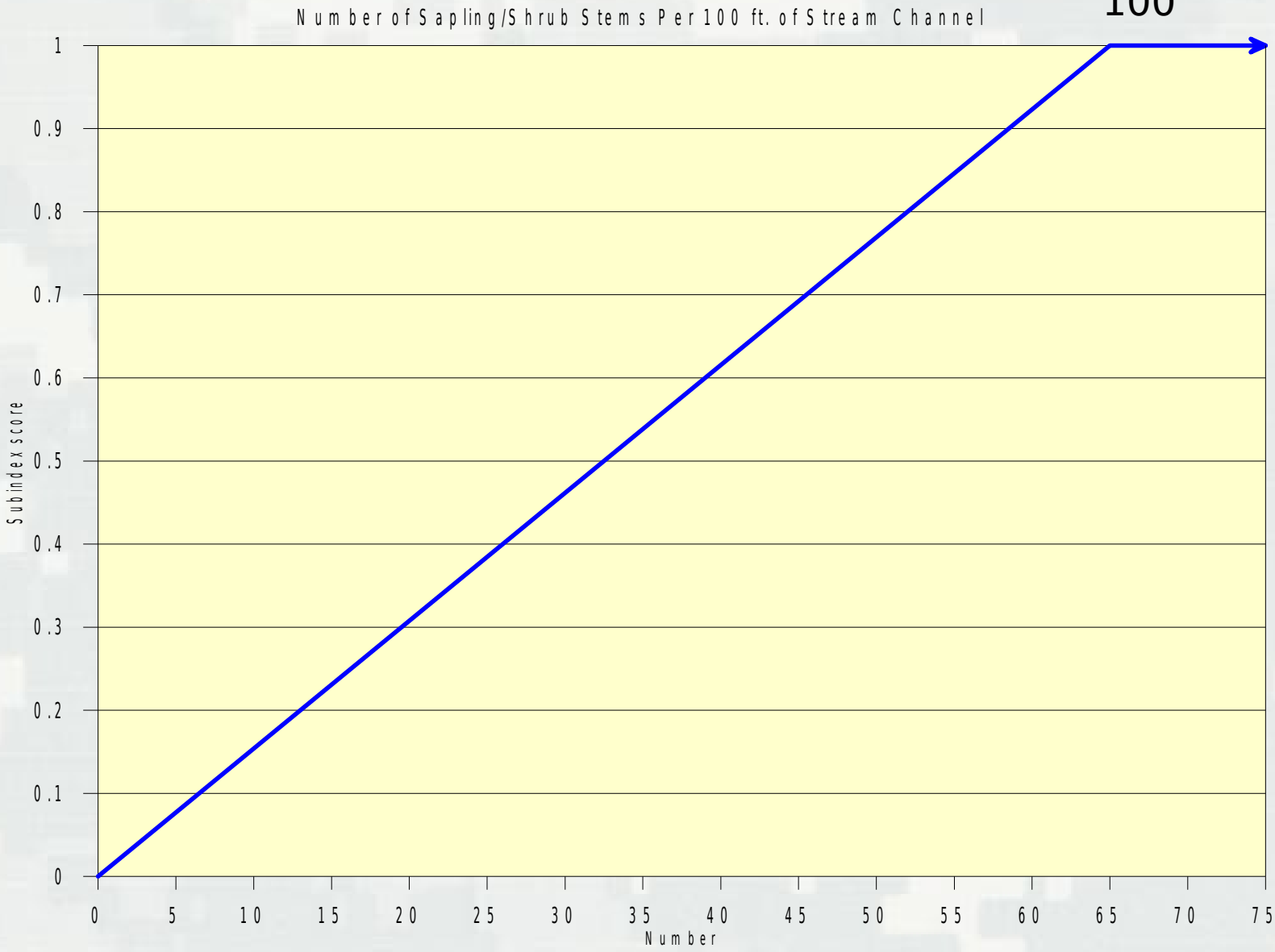
How to measure V_{SSD}

1) Count each woody stem within the entire riparian/buffer zone and the stream channel.
   - In cases where multiple stems arise from the same plant, count all stems above a height of 6 in. (15 cm) from the ground surface.
   - Stems that originate outside of the riparian buffer zone are not counted.
   - Record the total number of stems for the left side and right side of the sample reach on the datasheet

How to measure V_{SSD} (continued)

2) Total the number of stems within the riparian/buffer zone.
3) Divide the total number of stems by the length of the SAR or PSAR, then multiply by 100 to determine the number of sapling/shrub stems per 100 ft of stream reach.
4) Use Figure 23 to determine the variable subindex for V_{SSD}

≥65 per 100’


Number of Sapling/Shrub Stems Per 100 ft. of Stream Channel
Subindex score
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Number

Riparian/buffer zone species richness (V_{SRICH})

- Measure of the native tree species diversity per 100 ft of stream reach within the riparian/buffer zone and channel
- The focus is on the plants occurring in the tallest stratum present
- V_{SRICH} applies only to the habitat function

How to measure V_{SRICH}

1) On the data form, place a check mark beside each species in Group 1 or 2 (Table 5) that is observed in the riparian/buffer zone, including the channel.
2) Total the number of species checked in Groups 1 and 2 separately. Subtract the number of observed species in Group 2 from the number observed in Group 1. If the number from Group 2 is larger than that from Group 1, then the subindex score equals zero for V_{SRICH} and the following steps can be skipped.

How to measure V_{SRICH} (continued)

3) If the result of Group 1 – Group 2 is ≥ 8, then the subindex score is 1.0 regardless of the reach length and the following steps can be skipped.
4) For both Group 1 and Group 2, divide the number of species by the length of the SAR or PSAR being assessed; then multiply by 100 to determine the number of species per 100 ft of stream reach for each group.
5) Use Figure 24 to determine the subindex score for V_{SRICH}

Scientific Name	Common Name	Scientific Name	Common Name
Group 1		Group 2	
Acer rubrum	red maple	*Ailanthus altissima*	tree of heaven
Acer saccharum	sugar maple	*Albizia julibrissin*	silktree
Aesculus flava	yellow buckeye	*Alliaria petiolata*	garlic mustard
Asimina triloba	pawpaw	*Alternanthera philoxeroides*	alligatorweed
Betula alleghaniensis	yellow birch	*Aster tataricus*	tatarian aster
Betula lenta	black birch	*Cerastium fontanum*	common mouse-ear
Quercus alba	white oak	*Coronilla varia*	crownvetch
Carya alba	mockernut hickory	*Elaeagnus umbellata*	autumn olive
Carya glabra	pignut hickory	*Lespedeza bicolor*	shrub lespedeza
Carya ovalis	red hickory	*Lespedeza cuneata*	sericea lespedeza
Carya ovata	shagbark hickory	*Ligustrum obtusifolium*	border privet
Cornus florida	flowering dogwood	*Ligustrum sinense*	Chinese privet
Fagus grandifolia	American beech	*Lonicera japonica*	Japanese honeysuckle
Fraxinus americana	white ash	*Lonicera tatarica*	Tatarian honeysuckle
Liriodendron tulipifera	tuliptree	*Lotus corniculatus*	bird's-foot trefoil
Magnolia acuminata	cucumber-tree	*Lythrum salicaria*	purple loosestrife
Magnolia tripetala	umbrella-tree	*Microstegium vimineum*	Nepalese browntop
Nyssa sylvatica	blackgum	*Paulownia tomentosa*	princesstree
Oxydendrum arboreum	sourwood	*Polygonum cuspidatum*	Japanese knotweed
Prunus serotina	black cherry	*Pueraria montana*	kudzu
Quercus coccinea	scarlet oak	*Rosa multiflora*	multiflora rose

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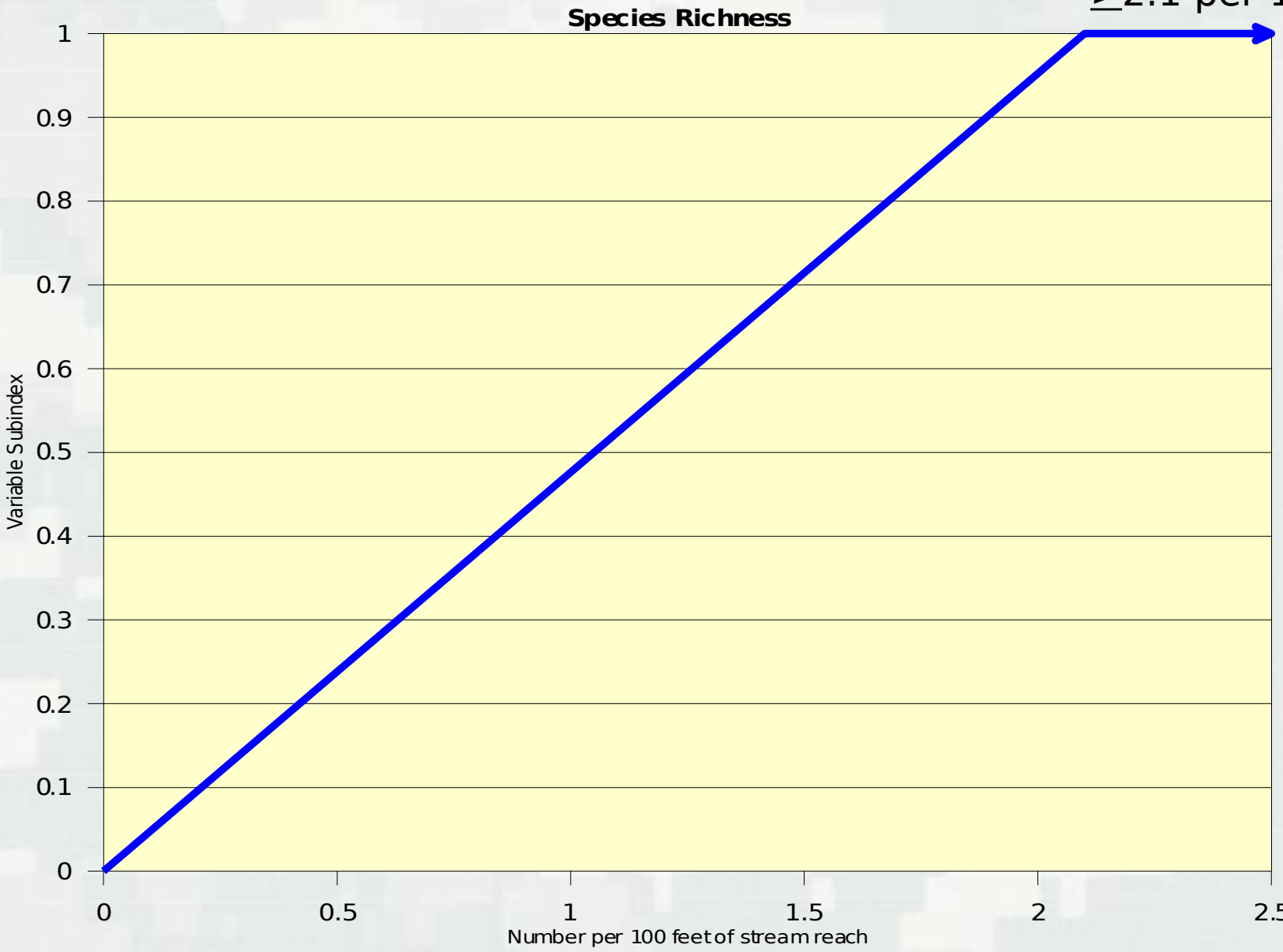
≥2.1 per 100’


Species Richness
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
Number per 100 feet of stream reach

Riparian/buffer zone soil detritus ($V_{DETRITUS}$)

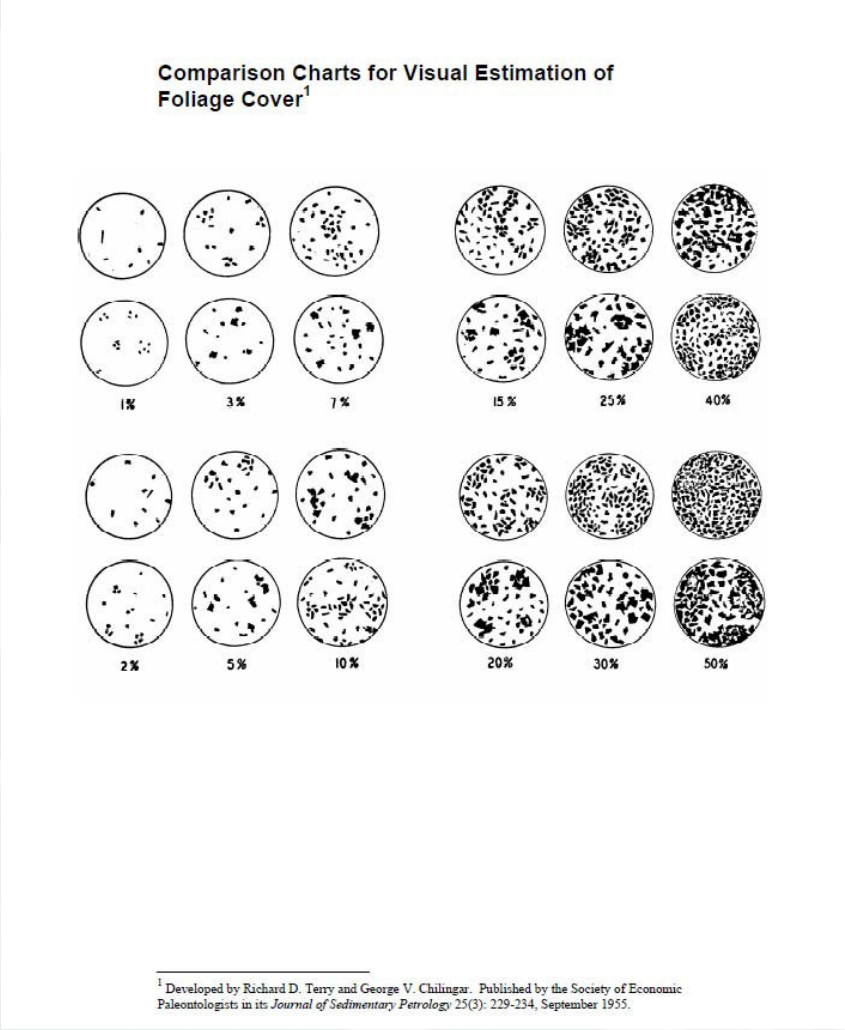
- Average percent cover of detrital material on the soil surface within the riparian/buffer zone
- Soil detritus is defined as the soil layer dominated by partially decomposed but still recognizable organic material, such as leaves, sticks, needles, flowers, fruits, insect frass, dead moss, or detached lichens on the surface of the ground
- Applies to the biogeochemistry and habitat functions

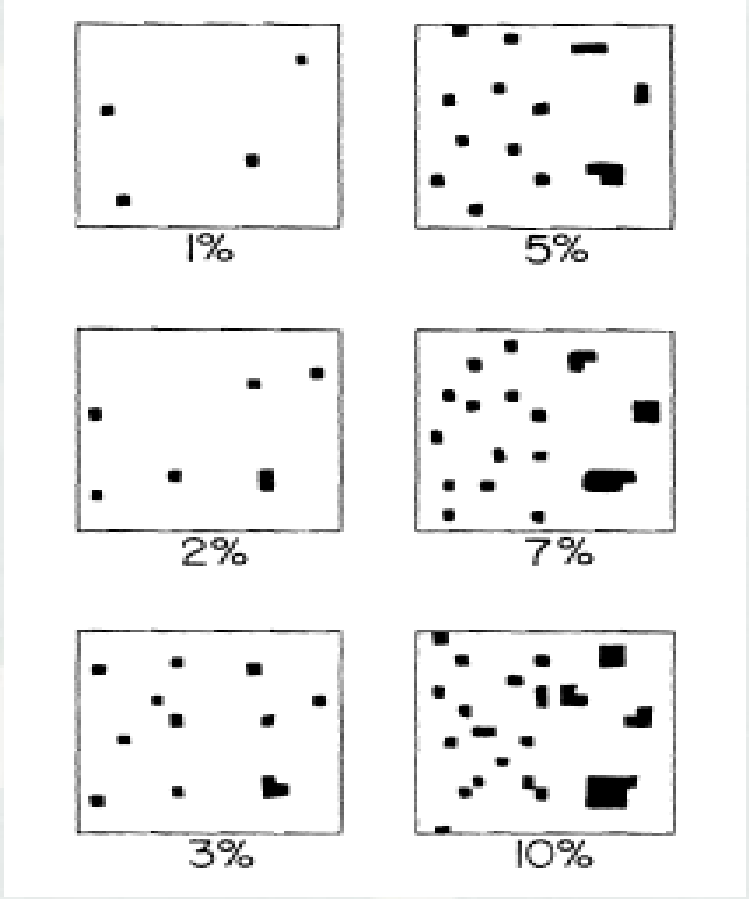
How to measure $V_{DETRITUS}$

1) Visually estimate the percent cover of leaves, sticks, or other organic material within eight or more 40-in. x 40-in. (1-m x 1-m) plots in representative locations of the riparian/buffer zone (four plots on each side of the channel).
2) Average the percent cover estimates of all plots.
3) Report the average cover of detritus as a percent.
4) Use Figure 26 to determine the subindex score for $V_{DETRITUS}$

How to measure $V_{DETRITUS}$

Examples of percent cover





82-100%

Riparian Detritus
Subindex Score
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
Percent riparian detritus

Riparian/buffer zone herbaceous cover (V_{HERB})

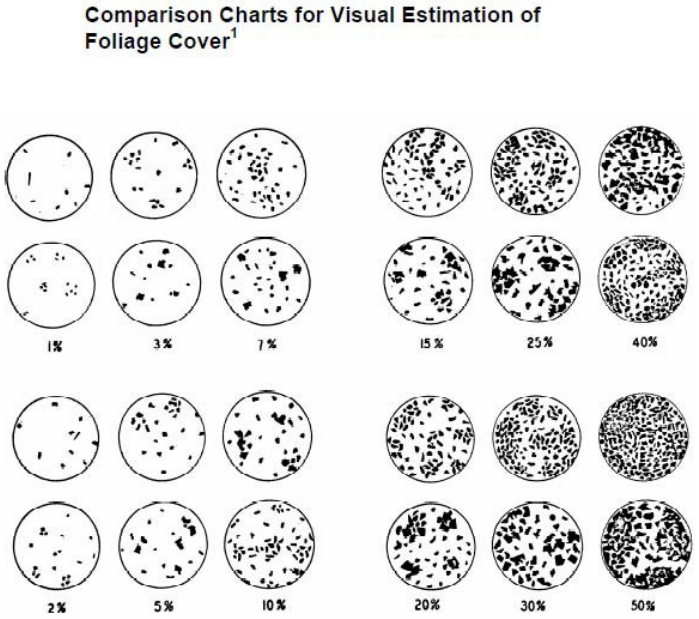
- Defined as all herbaceous vegetation, regardless of height (does not include woody species defined as sapling/shrub)
- Only measured if channel canopy cover is <20%
- Average percent cover of herbaceous vegetation within the riparian/buffer zone
- Applies to the biogeochemistry and habitat functions

How to measure V_{HERB}

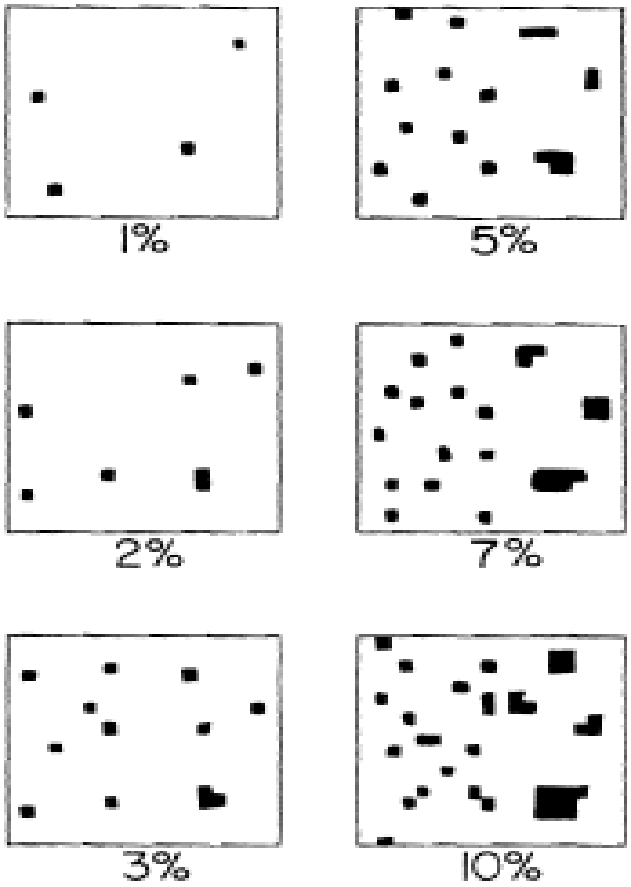
1) Using the same eight or more representative 40-in. x 40-in. (1-m x 1-m) plots used to estimate $V_{DETRITUS}$, visually estimate the percent absolute cover of herbaceous plant material
2) Average all estimates.
3) Use Figure 27 to determine the subindex score for V_{HERB}

How to measure V_{HERB}

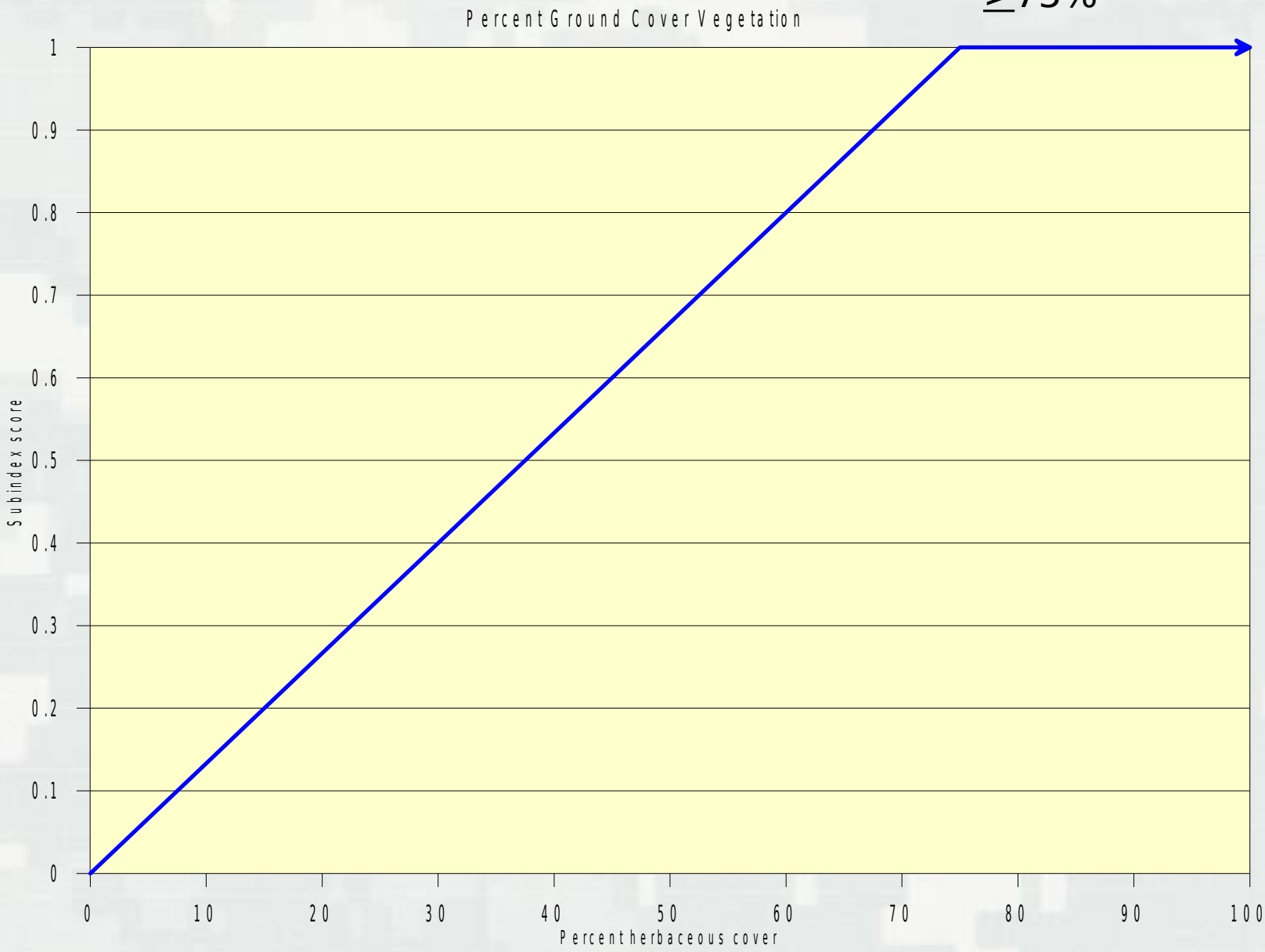
Examples of percent cover



[1] Developed by Richard D. Terry and George V. Chilingar. Published by the Society of Economic Paleontologists in its *Journal of Sedimentary Petrology* 25(3): 229-234, September 1955.



≥75%


Percent Ground Cover Vegetation
Subindex score
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
100
Percent herbaceous cover

Watershed land-use (V_{WLUSE})

- Surface runoff potential from the watershed or catchment outside the riparian/buffer zone into the headwater stream
- Weighted average of the combination of land cover and land-use classifications
- V_{WLUSE} applies to all functions

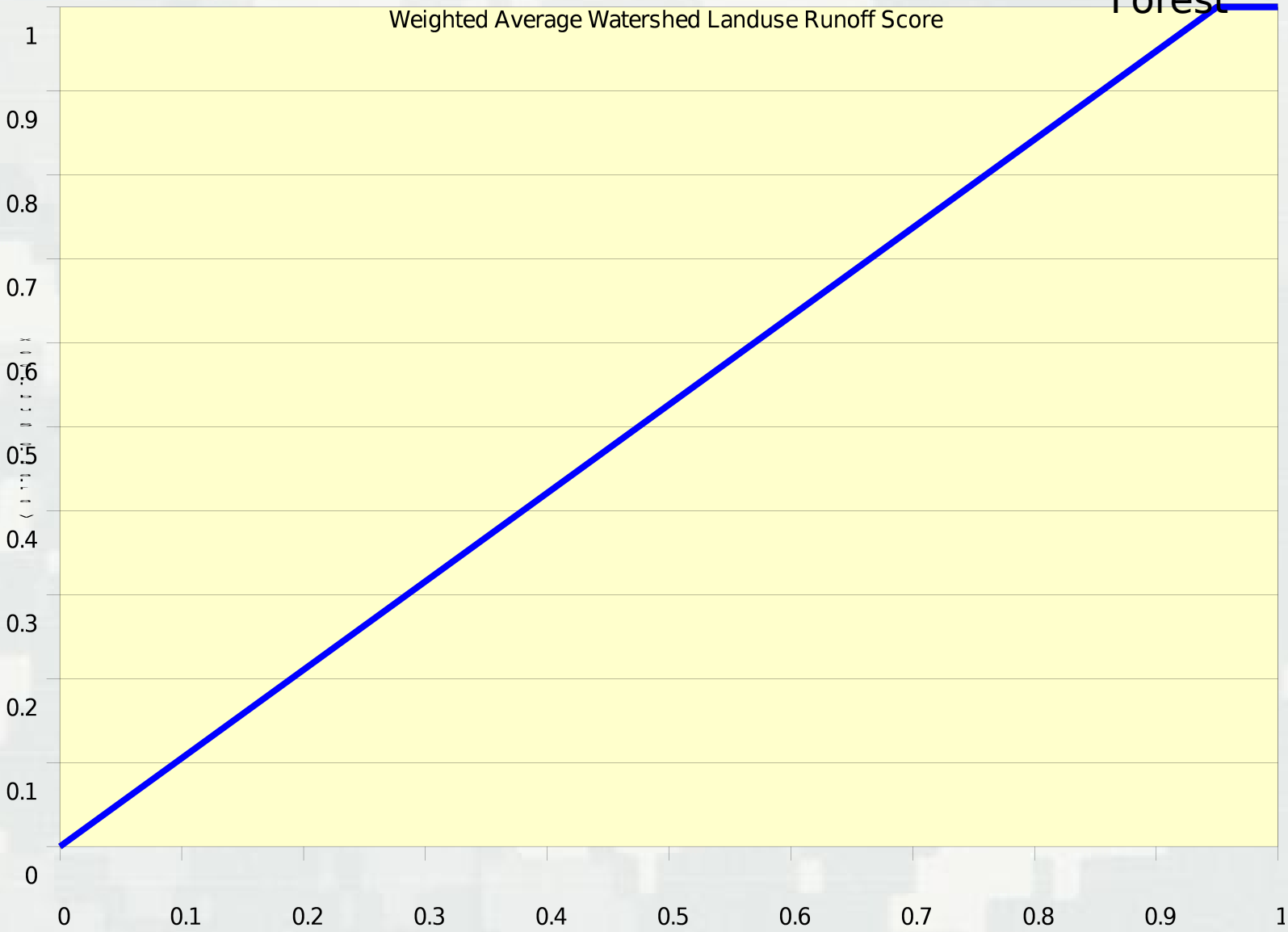
How to measure V_{WLUSE}

1) Use topographic maps, GIS data, or other sources to delineate the catchment or watershed above the lowest point of the SAR and along with field reconnaissance to determine the percentage of each land-use category (Table 5) in the watershed.
2) Determine a weighted average (by area) of land-use categories for the catchment. An example can be found in Appendix B.
3) Use Figure 28 to determine the subindex score for V_{WLUSE}

Table 6. Watershed land use.

Land use	Runoff score
Open space (pasture, lawns, parks, golf courses, cemeteries):	
Poor condition (grass cover <50%)	0.1
Fair condition (grass cover 50% to 75%)	0.2
Good condition (grass cover >75%)	0.3
Impervious areas (parking lots, roofs, driveways, etc)	0
Gravel	0
Urban districts:	
Industrial, commercial and business (≥70% cover)	0
Residential districts by average lot size:	
1/8 acre or less (town houses and apartments) (65% cover)	0
1/4 acre to 1/3 acre (38% to 30% cover)	0.1
1/2 acre to 1 acre (25% to 20% cover)	0.2
2 acres (12% cover)	0.3
Newly graded areas (bare soil, no vegetation or pavement)	0
Forest and shrub/sapling:	
Forest and native range (<50% ground cover)	0.5
Forest and native range (50% to 75% ground cover)	0.7
Forest and native range (>75% ground cover)	1.0

≥75% Native Forest



Data Sheet & Calculator

- HGM Guidebook available at: http://el.erdc.usace.army.mil/programs.cfm?Topic=wrap&Option=Program
  - ► Pages 68-70 in Guidebook
- Datasheet and FCI Calculator available at: http://el.erdc.usace.army.mil/wetlands/datanal.html

.

QUESTIONS?

HGM FUNCTION MODELS

Facilitated by LRL HGM Team:

Jennifer Thomason & Justin Branham

Louisville District Regulatory Branch

US Army Corps of Engineers
BUILDING STRONG®

Models

- Variables are combined using simple equations to represent differences in function based on deviation from reference standard
- One model for Hydrology function
- 2 models each representing Biogeochemical cycling and Habitat functions
  - ► One if Channel canopy is ≥20%
  - ► One if Channel canopy is <20%

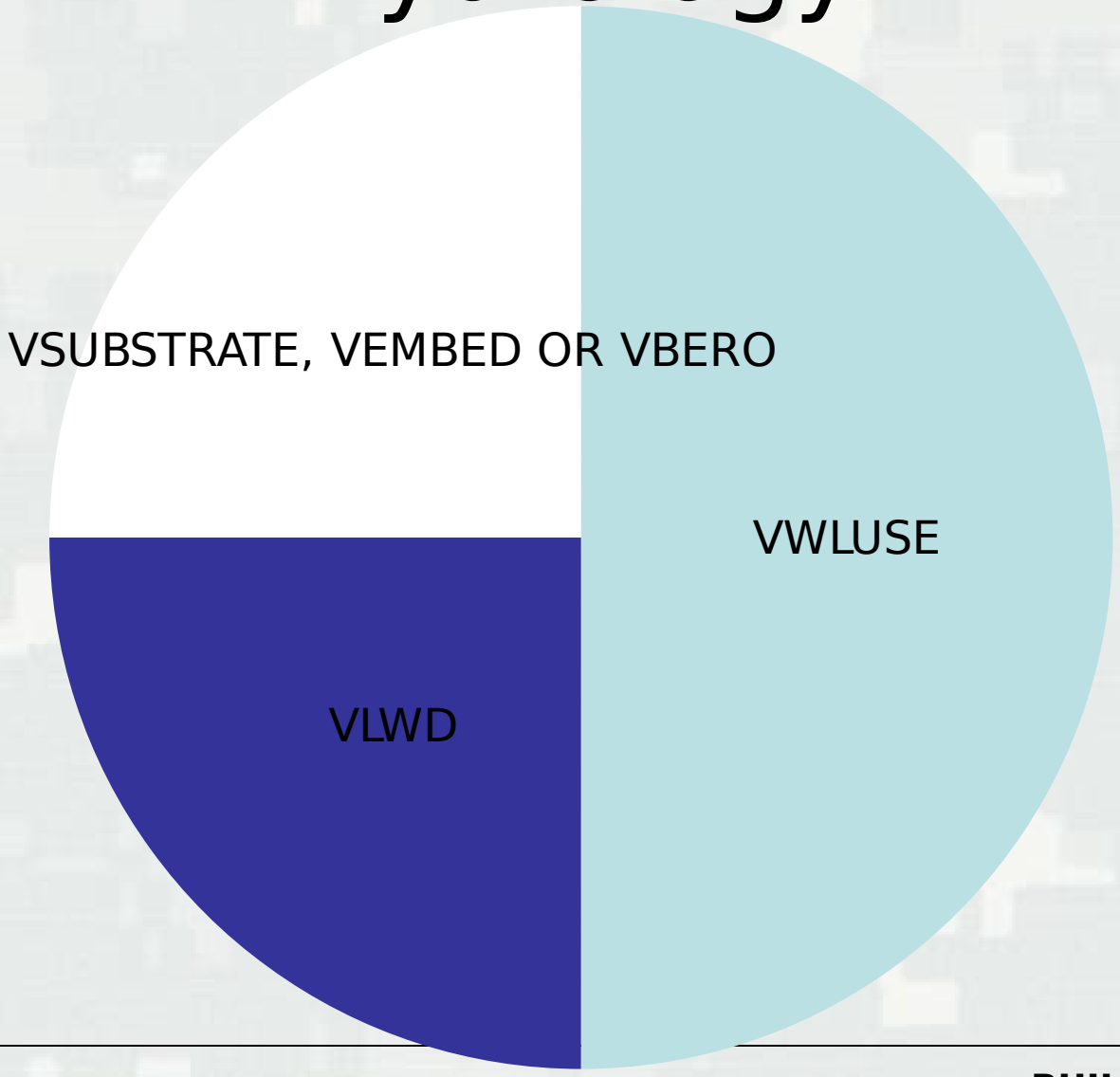
Hydrology

- Defined as the ability of the High-gradient Headwater Stream to dissipate energy associated with flow velocity and transport water downstream

Hydrology

- Substrate embeddedness
- Substrate size
- Potential bank erosion
- Large woody debris
- Watershed land use

Hydrology



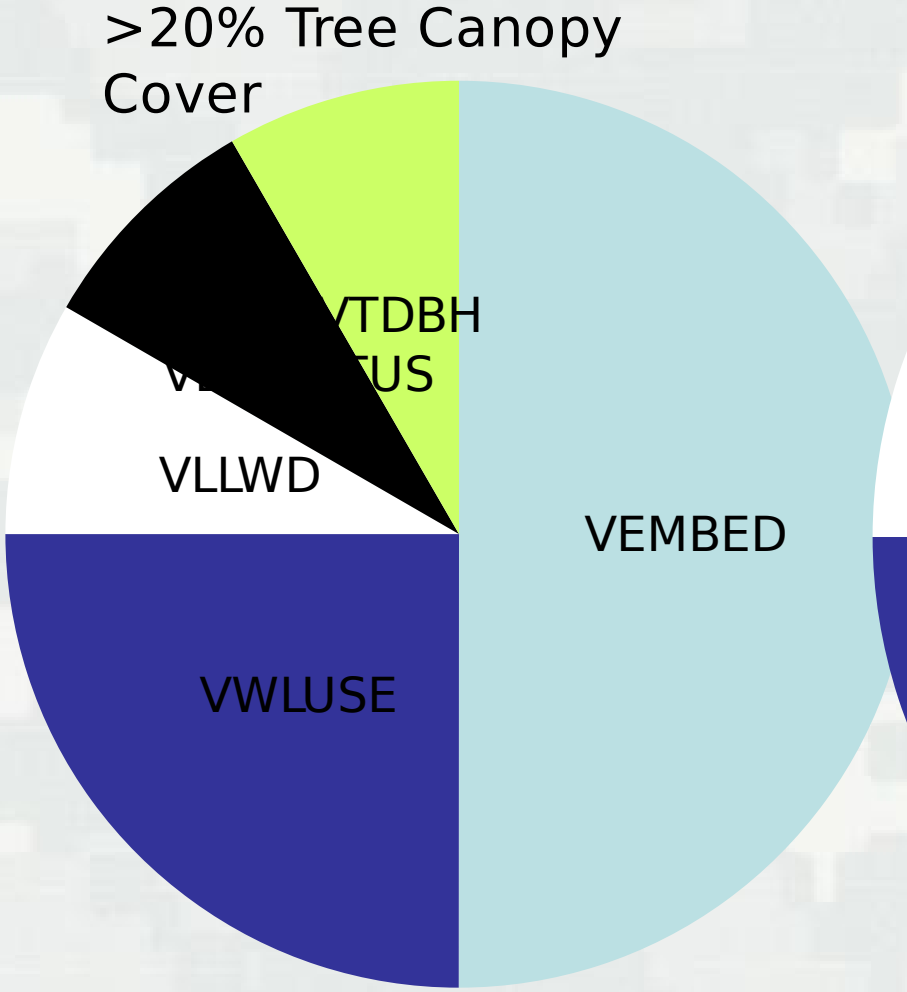
Biogeochemical cycling

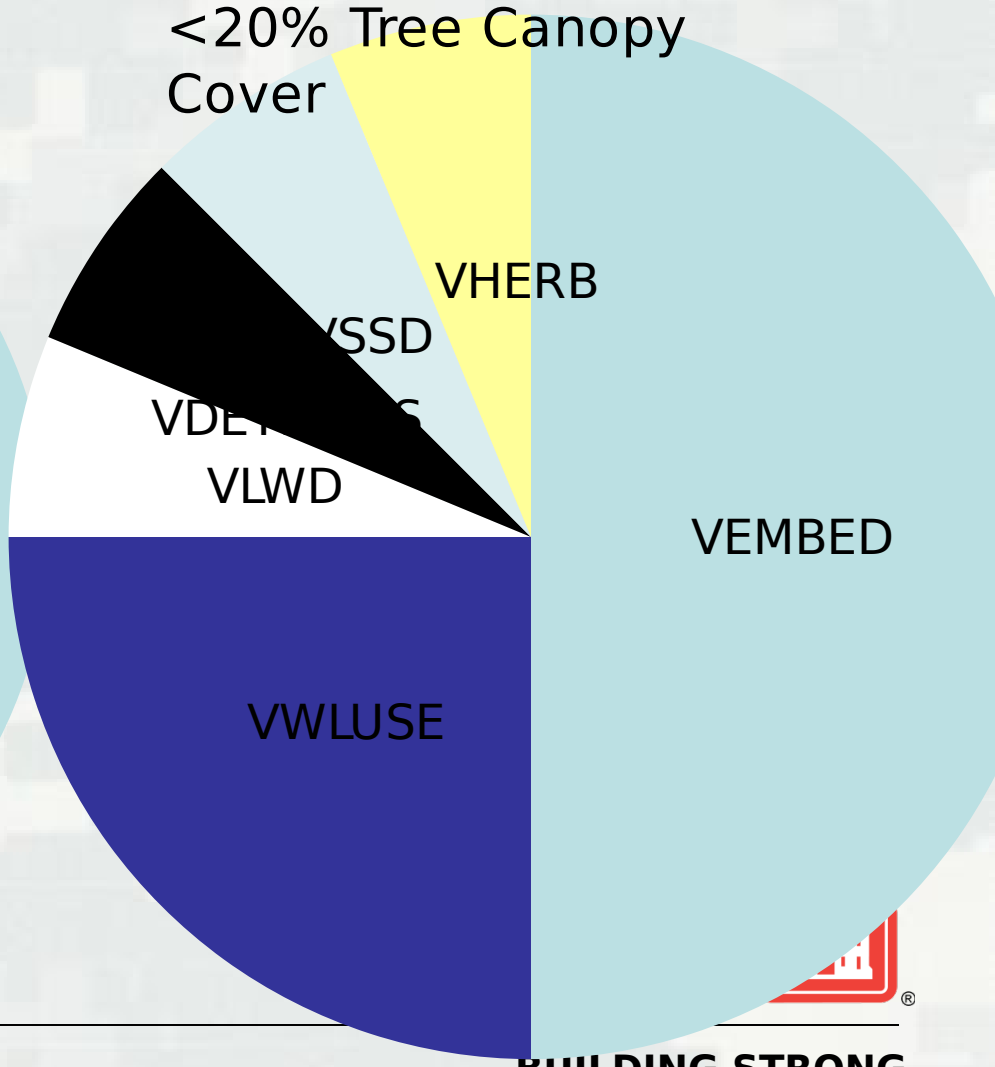
- Defined as the ability of the High-gradient Headwater Stream ecosystem to retain and transform inorganic materials needed for biological processes into organic forms and to oxidize those organic molecules back into elemental forms through respiration and decomposition

Biogeochemical cycling

- Substrate embeddedness
- Large woody debris
- Detritus
- Tree diameter at breast height
- Sapling/shrub
- Percent cover of herbaceous vegetation
- Watershed land use

Biogeochemical cycling





BUILDING STRONG®

Habitat

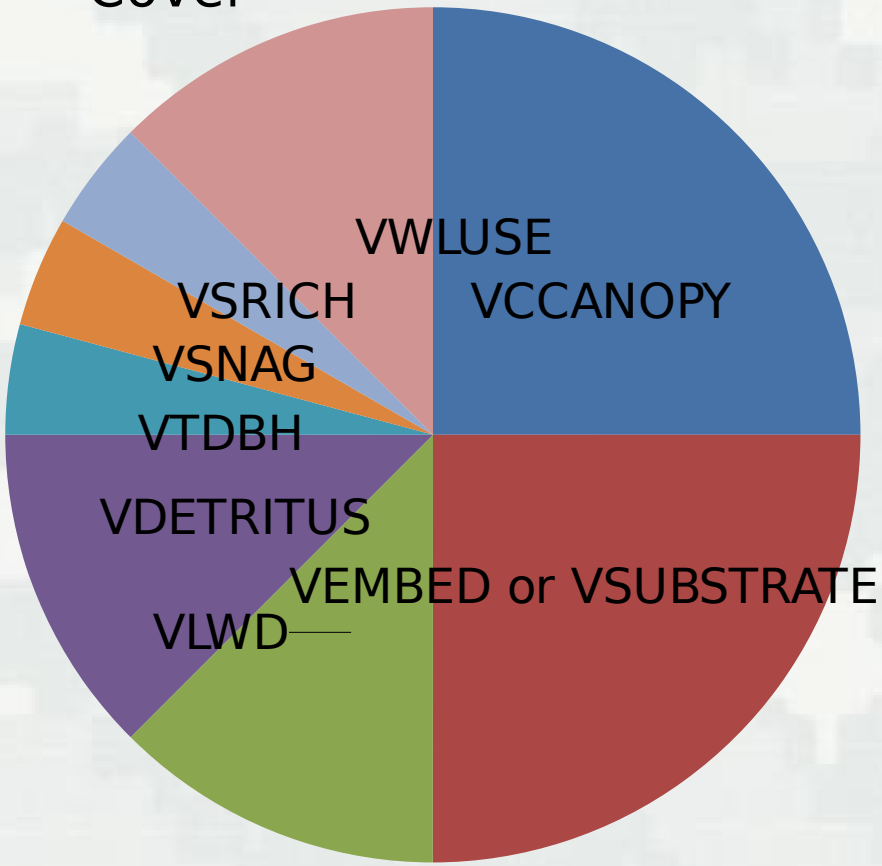
- Defined as the capacity of a High-gradient Headwater Stream ecosystem to provide critical life requisites to selected components of the vertebrate and invertebrate wildlife community

Habitat

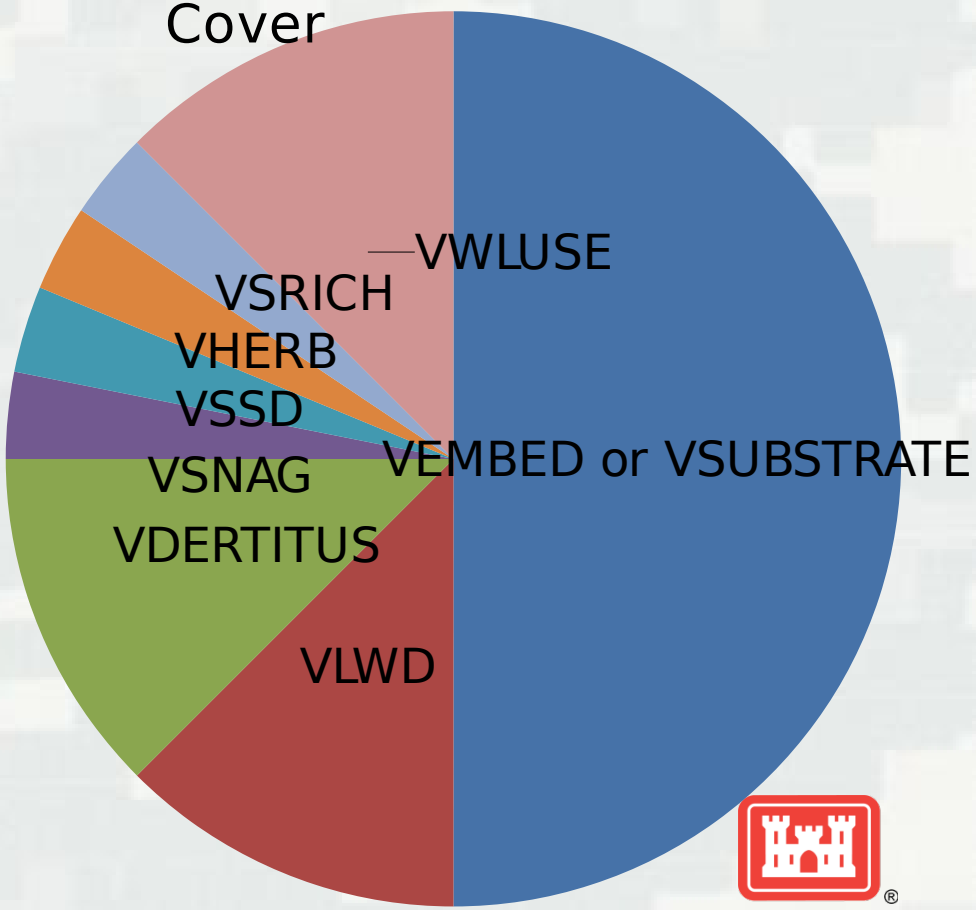
- Canopy cover
- Substrate embeddedness
- Substrate size
- Large woody debris
- Detritus
- Tree diameter at breast height
- Snag density
- Sapling/shrub density
- Species richness (tree or tallest dominant strata present)
- Percent cover of herbaceous vegetation
- Watershed land use

Habitat

>20% Tree Canopy Cover



<20% Tree Canopy Cover



QUESTIONS?